

North Korean ELWR makes progress towards operations

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North Korea has made progress in late 2017 on its experimental light water reactor at Yongbyon. *Allison Puccioni* and *Elliot Serbin* demonstrate how multiple intelligence sources can produce a better understanding of the reactor's operations.

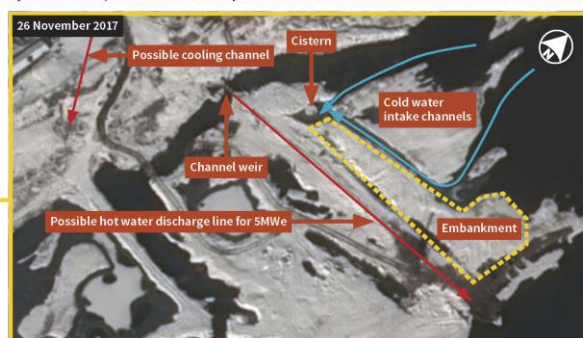
North Korea's successful test of a likely boosted fission or hydrogen (thermonuclear) bomb on 3 September 2017 and its multiple launches of intercontinental ballistic missiles (ICBMs) and shorter-range missiles in 2017 have challenged open-source intelligence (OSINT) analysts' understanding of Pyongyang's developing nuclear capabilities.

Gaps in intelligence are particularly pertinent to the country's Nuclear Scientific Research Center at Yongbyon, 75 km north of Pyongyang. This facility accounts for all of North Korea's known nuclear weapons material, but is rarely mentioned in North Korean propaganda and indeed may never have hosted an official visit by Supreme Leader Kim Jong-un or his father, Kim Jong-il.

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Airbus Defence and Space imagery showing the 5 MWe and experimental light water reactor (ELWR) at Yongbyon. Hot water is discharged from the active cooling system from the 5 MWe reactor into the Kuryong River. In winter months, this melts frozen water upriver from the intake channel of the ELWR's cooling system. By November 2017, two channels were completed that funnelled water into an intake cistern of the ELWR's cooling system.



Airbus Defence and Space imagery showing components of the ELWR's cooling system. Throughout 2017, engineering equipment, including excavators and cargo trucks, was used to build an embankment between the cold water intake channels and the probable hot water discharge cooling channel downriver.

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Airbus Defence and Space imagery (top image) showing the 5 MWe and experimental light water reactor (ELWR) at Yongbyon. Hot water is discharged from the active cooling system from the 5 MWe reactor into the Kuryong River. In winter months, this melts frozen water upriver from the intake channel of the ELWR's cooling system. By November 2017, two channels were completed that funnelled water into an intake cistern of the ELWR's cooling system. Below, imagery shows components of the ELWR's cooling system. Throughout 2017, engineering equipment, including excavators and cargo trucks, was used to build an embankment between the cold water intake channels and the probable hot water discharge cooling channel downriver. (© CNES 2017, Distribution Airbus DS / © 2018 IHS Markit)

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Recapping OSINT capabilities

Unlike media and academic organisations, some governments and military intelligence agencies have technologically advanced and long-established means of collecting information on North Korea. This includes electronic signals (SIGINT and ELINT), communications intercepts (COMINT), human intelligence (HUMINT), measurement and signatures intelligence (MASINT), and imagery intelligence (IMINT).

Information derived from conventional intelligence tradecraft is largely unavailable to the public, but an increasing number of commercial sensors and datasets have emerged over the past decade. Increasingly, these datasets enhance the understanding of the North Korean threat in the open-source community, particularly when the resources are used in concert.

A number of openly available sources of information shed light on North Korea's strategic nuclear programme. Pyongyang's own propaganda apparatus includes the North Korean state news agency, Korean Central News Agency (KCNA); the state-owned broadcaster, Korean Central Broadcasting Committee; and the Party daily, *Rodong Sinmun*. These state-run entities publish reports, photos, and video that the government chooses to show its citizens and the outside world.

For example, KCNA frequently reports on military events as a means of projecting the nation's strategic competence, including a series of multiple ICBM tests throughout 2017. These reports are useful to experts in the open-source community, who routinely geolocate KCNA-published images against satellite imagery to determine the precise locations and granular details of strategic events.

Outside media with well-placed sources in North Korea are rare but do exist, often reporting via North Korean expatriate or diaspora populations in Japan or through government intelligence sources, such as the South Korean National Intelligence Service (NIS). This information is often impossible to vet through conventional journalistic tradecraft, but is reported because of the absence of other information. For example, when the nuclear test site Punggye-ri may have had a serious accident on 31 October 2017, this was first reported by the North Korean expatriate population in Japan through TV Asahi.

International organisations such as the United Nations and its nuclear monitoring arm, the International Atomic Energy Agency (IAEA), occasionally release reports about North Korea's nuclear fuel cycle and illicit import or export activity. The provenance of this information is often omitted, or is credited as deriving from 'a member nation'. Such a designation signifies that the information was likely provided by a nation's intelligence apparatus, indicating that it originates from intelligence tradecraft.

Important insight about North Korea's nuclear capability has also been gleaned from sparse foreign visits to Yongbyon. Reports emanating from numerous IAEA visits to Yongbyon are still valuable sources of information, even including a 1992 visit in which then IAEA director general Hans Blix – the head of the agency from 1981 to 1997 – extensively detailed the specifics of the facility.

Between 2004 and 2010, in the context of the so-called Six-Party Talks aimed at finding a solution to Pyongyang's nuclear programme, scientists and policy experts from CISAC were invited annually to North Korea, possibly for the leadership to credibly convey that it possessed a nuclear deterrent. Over the course of those seven years, Dr Siegfried Hecker – a former director of the US Los Alamos National Lab and former co-director of CISAC – visited Yongbyon four times. Hecker's written accounts and photographs of his visits, including the influential 2010 report *A Return Trip to North Korea's Yongbyon Nuclear Complex*, form much of the basis of understanding of North Korea's nuclear capability for the outside world.

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DigitalGlobe imagery showing continued engineering work over the Kuryong River. The embankment has been extended to the eastern bank of the river, redistributing the channel towards the experimental light water reactor (ELWR) cooling system on the west bank. Summer flood patterns suggest that this may be a temporary effort to melt and channel as much of the river as possible to the ELWR, a further indication of imminent activity.

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DigitalGlobe imagery showing continued engineering work over the Kuryong River. (© 2017 DigitalGlobe, Inc./© 2018 IHS Markit)

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Multiplying sources

In 2017, CISAC began a multi-source approach to studying Yongbyon, involving the study of granular analysis of high-cadence, high-resolution commercial satellite imagery (including 44 images taken of Yongbyon alone in 2017). The academic study compartmentalised Yongbyon into multiple 'sub-facilities', and each image – itself a timestamp of activity for the date the image was collected – was analysed for nuanced elements of activity, including the presence of vehicles, personnel, equipment, and smokestack effluent.

Throughout 2017, CISAC recorded thousands of observables that were further scrutinised by experts in imagery analysis, North Korean policy, and nuclear engineering. The resulting study fuses multiple analytical components with regional and disciplinary expertise, which yields nuanced characteristics about the function and operational status of specialised facilities.

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Critical activity at Yongbyon

The CISAC multi-sensor and multi-source study has assessed that sub-facilities throughout Yongbyon were active in nuclear weapons production throughout 2017. A noteworthy increase in activity was at the new experimental light water reactor (ELWR). *Jane's* first confirmed construction of a new reactor in November 2010, using satellite imagery to corroborate Hecker's report upon his return from his visit to Yongbyon, during which the facility's directors had told him about the ELWR's existence.

The ELWR was designed as an entry into electricity production, and although the exterior of the reactor building was completed in 2013, it remained relatively stagnant and never became 'critical' or operational. Possible delays in the start-up of the reactor – according to Hecker, nuclear engineering expert Dr Chaim Braun, and Dr Chris Lawrence, writing in *The Korea Observer* in 2016 – included the need to fabricate a new type of reactor fuel (requiring the manufacture of ceramic uranium dioxide [UO_2]); the continued construction and testing of internal components; the development of proper cladding materials; uncertainties about the cooling system; and general inefficiencies in starting up a new reactor in the hands of inexperienced engineers.

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In the early and late months of 2017, snowmelt was visible at a building within the Yongbyon complex that may be associated with fuel rod production for the ELWR. This building originally produced fuel rods for the 5 MWe reactor until that production was transferred to a facility closer to the 5 MWe, and is judged by CISAC to have continued with fuel rod production for the ELWR.

The melt at the building was localised to parts of the roof and at the adjacent waste-water pond. There was no snowfall between the local spring and early autumn seasons, but water levels in the waste-water pond fluctuated and debris piles expanded outside the building. These observables suggest that the building was likely operational throughout the year in the possible manufacturing of fuel rods for the ELWR.

A nuclear reactor requires an elaborate cooling system. North Korea's existing 5 MWe reactor, which is 110 m upriver from the ELWR, uses pumped-in water from the Kuryong River as its cold-water intake, then discharges heated water downriver as a means of heat exchange for the overall cooling system. The ELWR's cooling system has been under construction since 2013 but took form in the final months of 2017.

In March and April 2016, dredging and construction equipment were present immediately southeast of the ELWR at the bank of the Kuryong River, emplacing a small structure resembling a small dam – or weir – in the middle of a river trench. This may have been an attempt to control water flow into the intake channel for the ELWR's cooling system.

Additionally, a 1-m wide possible conduit was visible in imagery between September 2016 and August 2017, extending across a newly-engineered riverbank into the Kuryong River. Through the local spring to autumn months of 2017, construction and engineering vehicles were also visible

around this conduit, which may be a component of the ELWR's cooling channel, in addition to another conduit that terminates 170 m downriver. According to analysis by CISAC affiliate Nick Hansen, the downriver conduit was constructed in 2011 when North Korea built the first river cooling system at the reactor. This conduit was tested in 2013, and now terminates into a large pond cordoned off by an engineered embankment from the Kuryong River.

By November 2017, construction equipment was evident dredging a large land mass in the Kuryong River to serve as an embankment separating an upriver channel that funnels river water into the ELWR cold-water intake cistern and the downriver conduit of the water-cooling channel. This riverbank was designed to prevent down-river hot water from re-circulating into the cold-water intake channel.



Airbus Defence and Space imagery showing power lines leading to the experimental light water reactor (ELWR) at Yongbyon. Although the power lines are merely a few centimetres thick, they are visible against the dark background of the Kuryong River. The power transmission line was erected adjacent to the ELWR's electrical sub-station between 14 March and 9 April 2017, and the line was first visible on 13 September. The three-phase line runs from the tower across the river, where visibility is precluded by the vegetation.

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Because the Kuryong River often freezes during winter, North Korean engineers appear to have designed the ELWR's cooling system in an ingenious way. It uses the hot water discharged from the water-cooling channel of the 5 MWe reactor to melt river water up-river, and this provides a fresh supply of melted river-water to the ELWR's cold-water intake channel. The result is a viable cooling system necessary for the ELWR's operation during any month. Additionally, dredging is

under way up-river from the 5 MWe and around the ELWR to stem the flow of the Kuryong River during the summer monsoon months.



Airbus Defence and Space imagery showing construction prior to the erection of the power transmission tower adjacent to the experimental light water reactor (ELWR) at Yongbyon.



Airbus Defence and Space imagery showing the completed power transmission tower adjacent to the ELWR at Yongbyon. The tower itself is barely visible in the imagery; the shadow that it casts is more distinct.

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Airbus Defence and Space imagery (above) showing construction prior to the erection of the power transmission tower adjacent to the experimental light water reactor (ELWR) at Yongbyon. Below, imagery shows the completed power transmission tower adjacent to the ELWR at Yongbyon. The tower itself is barely visible in the imagery; the shadow that it casts is more distinct. (© CNES 2017, Distribution Airbus DS / © 2018 IHS Markit)

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Imagery analysis throughout 2017 also indicated that the ELWR was being connected to the local electrical grid. In March 2017, excavation was visible adjacent to the ELWR's electrical transfer substation, and by 9 April 2017 a power transmission tower was upright and visible at that site.

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Pre-operational activity

Cumulative analysis indicates that the ELWR reactor building is undergoing maintenance and testing. Speaking to *Jane's* in late December, Braun suggested that this may be 'pre-operations'

testing of the reactor's pumps and valves, associated with operations and cooling that must be conducted prior to full operation.

Beginning in April 2017, significant activity included the presence of vehicles, personnel, material, and engineering equipment, which were intermittently congregated around the ELWR's north-facing entrance at its reactor dome. Such activity was also observed in May and July, with a noteworthy presence of personnel, vehicles, ground discoloration, and material throughout May 2017.

By 6 July, a tower crane was emplaced at the reactor dome entrance and remained until the end of August. This crane – along with the abundance of activity concentrated around the reactor dome entrance – may have transferred reactor components, including fuel, into the reactor building. However, by 29 October, the activity around the reactor diminished.

Subsequently, by the first snowfalls of late 2017, patterns of snowmelt indicated evidence of activity that was possibly in support of pre-critical operations testing. Snowmelt on other facilities throughout Yongbyon has aided OSINT analysts and has often provided the only indication of heat (and therefore objective evidence of a building's operation).

Snowmelt was observed at the ELWR in February 2017 between the reactor dome and the operations room, and in part on the reactor roof on four dates (18, 19, 20, and 26 November). This may be a result of daylight sun exposure, but patterns around the reactor dome and adjacent building in February and November 2017 may indicate pre-operational activity within the building. Snowmelt was also evident along the water-cooling conduit in November 2017, indicating warmer water from the 5 MWe reactor was reaching the ELWR's intake channel and the ELWR's cooling system may have been undergoing testing.

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Imminent ELWR operation

The intelligence yields a conclusion of an imminent significant advance in North Korea's nuclear capability. Once online, the ELWR will provide nuclear energy production and a pathway forward for a greater and more systemised nuclear capability. The primary purpose of the ELWR, as declared by North Korea through KCNA statements, is to demonstrate an experimental capability for the light water reactor production of electricity for civilian use.

This electricity output would be limited: once operational, the ELWR would be able to produce approximately 25–30 megawatts, perhaps enough to power the small city of Yongbyon 4 km to the northeast. It could therefore serve as a pilot project for a larger nuclear energy infrastructure.

Moreover, the operation of this reactor would be symbolic for North Korea, whose desire for a light water reactor to develop its nuclear energy industry dates back to the later years of the Cold War, when it sought but failed to obtain one from the Soviet Union. It also embarked on a failed endeavour to obtain light water reactors from international sources in the 1990s and 2000s. Finally, in 2009, Pyongyang publicly announced that it would indigenously build a reactor. With the ELWR operational, the government will be able to promote indigenous reactor production and operation as a major accomplishment and component of its 'juche' principle of self-reliance.

However, the ELWR could also be used to produce critical elements of North Korea's nuclear weapons programme. Indeed, the hastening of its operation after a relatively stagnant period may indicate a potential for dual use.

Analysis of North Korea's September 2017 bomb test – based on revealed designs and yield – indicates that it may have been either a boosted fission or hydrogen (thermonuclear) device. The test indicated that North Korea had the indigenous capacity to produce tritium, which is a key component in such a device. North Korea is likely to have a small tritium inventory obtained from the operation of the 5 MWe reactor. It may also have used its Soviet-supplied IRT-2000 small research reactor for tritium production, although this reactor's history of irregular operation makes this unlikely.

North Korea's rate of development of high-yield warheads sufficiently compact to mount on an ICBM will be determined, in part, by the rate at which it can produce and maintain its tritium stockpile. Tritium could be produced in lithium-6 targets in the ELWR during shorter 'burn cycles', which would not be the typical mode of operation for electricity generation. These 'targets' are special rods filled with lithium-6 that are irradiated in the reactor core, with the lithium in the rods being converted to tritium when it is irradiated by neutrons.

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Author

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